National Aeronautics and
Space Administration

High Temperature Liquid Crystal Thermosets

New polymer chemistries benefit processing and performance

TECHNOLOGY OPPORTUNITY

NASA Langley has a family of chemistries and supporting patents related to a series of liquid crystalline materials that have several distinct advantages over currently available commercial liquid crystalline polymers (LCPs). The NASA materials use low-melting, all-aromatic ester-based liquid crystal oligomers end-capped with reactive phenylethynyl end groups. This reactive oligomer approach enables synthesis of liquid crystal thermosets with outstanding mechanical and thermal properties that are superior to well-known high-performance polymers such as PPS and PEEK. NASA's chemistries offer inexpensive and adaptable materials for melt processing complex shapes using resin transfer molding or resin film infusion techniques. The low coefficient of expansion, combined with excellent barrier properties, makes this new technology useful for cryogenic applications and other applications that involve extreme temperature changes. In addition, the excellent barrier properties make these materials chemically resistant to acids, bleaches, chlorinated solvents, alcohols, and hydrocarbon fuels.

BENEFITS

- A much broader process window than typical LCPs. End groups are stable in the melt up to 300°C (1 hour), which gives ample time for processing
- Inexpensive—uses commercially available monomers and standard melt polymerization techniques
- Improved mechanical properties and thermal stability (T_g>250°C, T_{dec}~500°C)
  - Final product remains in its liquid crystalline state after curing, which enables improved chemical resistance and excellent barrier properties to small molecules
  - The low CTE and amorphous nature will allow for the fabrication of thick structures without internal stresses
  - Low melt viscosity (as low as 7 poise at 100 rad.s^{-1})
  - Low dielectric constant
- Flame retardancy and low smoke generation – these resins typically have a UL94 VO rating
- Good adhesive properties—optimum lap-shear and Tg is 5,000 to 9,000 g.mol^{-1}

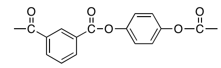
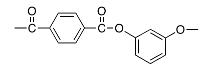
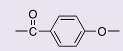
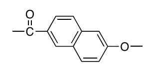
PATENTS

U.S. Patents 7,507,784 and 6,939,940, which are both titled "Liquid Crystalline Thermosets from Ester, Ester-Imide, and Ester-Amide"

COMMERCIAL APPLICATIONS

The technology offers wide-ranging market applications, including:

- Electronics – precision parts including connectors, integrated circuits, circuit breakers, sockets, minibobbins, fuse holders
- High-performance materials
  - high strength fibers for applications like tire cord
  - high strength films for applications like packaging
  - coatings, foams, and composites for applications such as:
    - vessels and piping that require solvent resistivity for chemical processing
    - replacing stainless steel in surgical instruments and sterilization trays
    - o-rings, gaskets, foam-in-place sealants, and high-performance adhesives
    - parts, panels, fans, heat exchangers, rocker covers, fuel tanks that require textile reinforced composite materials for use in aeronautic and automotive markets

Thermal Properties							
Sample	**T_m(°C)**	T_d(°C) N_2/Air	**Char Yield (wt %)**	**E' (GPa) at (25°C)**	**E' (GPa) at (200°C)**	Tg (°C)	
TA/HQ/**IA**(25)-5K	340*	486/458	51	–	–	–	
TA/HQ/**IA(**50)-5K	315	470/451	52	4.2	1.2	220	
TA/HQ/**IA(**75)-5K	321	468/457	58	3.2	1.1	243	
TA/HQ/**RS(**50)-5K	316	469/459	56	4.9	1.5	259	
TA/HQ/**HBA(**50)-5K	328	486/475	50	3.2	1.8	225	
TA/HQ/**HNA(**25)-5K	290	490/478	52	3.9	0.7	186	

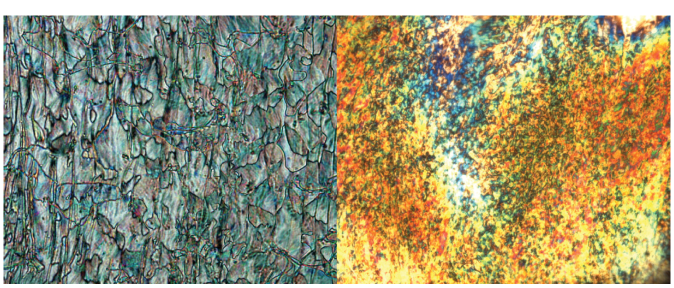
Mechanical Properties of Thin Films	**Tg (°C)**	**E' (GPa) at 24°C**	**Tensile strength (MPa) at 24°C**	**Elongation at break (%) at 24°C**
HBA/HQ/IA-9K cured at 340°C	206	7.1	69	3
HBA/HQ/IA-9K cured at 370°C	184	3.9	83	10
HBA/HQ/IA-9K cured at 400°C	175	3.3	64	2

Carbon Fiber Composite Properties 40x40 cm, 6 ply (60/40) T300 5H satin weave All-aromatic HBA/HQ/IA(32)-9k	**LCT** Tg = 180°C	**PPS*** Tg = 95°C	**CETEX PEI*** Tg = 210°C
Tensile strength (MPa)	671	592	656
Flexural Modulus (GPa)	51	60	50
In-plane shear strength (MPa)	154	119	118
In-plane shear modulus (GPa)	3.7	4.0	3.4

* Data as provided by Ten Cate, room temperature data only

TECHNOLOGY DESCRIPTION

Depending on the backbone chemistry and the molecular weight (controlled by reactive end group concentration), NASA has developed various liquid crystalline resins (LCRs) with a wide range of physical and chemical properties. Low concentrations of reactive end groups (e.g., a 9000 g.mol-1 oligomer) give a low viscous thermotropic melt (10–200 poise at 100 rad.s-1). When cured, a high Tg (>200°C) nematic thermoset is obtained that provides an excellent combination of toughness and stiffness.



Representative Micrographs (Polarizing Optical Image). Left image: Microphotograph, LCR-1k 370°C melt, (20x) Low viscous nematic threaded Schlieren texture. Right image: Microphotograph, LCR-1k cross-linked 1 h. 370°C, (20x) nematic thermoset

FOR MORE INFORMATION

If your company is interested in licensing or joint development opportunities associated with this technology, or if you would like additional information on partnering with NASA, please contact:

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